ECONOMIC ASSESSMENT OF THE IMPACTS OF CATARACTS

Prepared by:

Robert D. Rowe
Tina N. Neithercut
Energy and Resource Consultants, Inc.
PO Drawer O
Boulder, CO 80306
(303) 449-5515

William D. Schulze
Center for Economic Analysis
University of Colorado
Boulder, CO 80306
(303) 492-5242

Prepared for:

Dr. Alan Carlin (PM-220)
Benefits Branch - OPPE
U.S. Environmental Protection Agency
401 M Street, SW, Room W427A
Washington, DC 20460

March 1987

(IBALL)

DISCLAIMER

Although prepared with EPA funding, this report has neither been reviewed nor approved by the U.S. Environmental Protection Agency for publication as an EPA report. The contents do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ACKNOWLEDGEMENTS

Robert D. Rowe
Boulder, Colorado
January, 1987

ECONOMIC ASSESSMENT OF THE IMPACTS OF CATARACTS

ABSTRACT

As part of its stratospheric ozone protection program, the U.S. Environmental Protection Agency is conducting analyses of the effects of ultraviolet radiation (UV-B) on human health. Among other effects, UV-B may contribute to the increased incidence of cataracts. This report provides preliminary economic estimates of the damage to the affected individual and to society for new cases of cataracts.

The report focuses upon the damage of actually incurring cataracts, as opposed to the value to individuals of preventing increased risks of incurring cataracts in the future. This approach was employed to accurately obtain actual cost and value data for actual cataracts impacts to affected individuals and to society, but comes at the expense of not measuring risk premiums. Two economic measures of cataracts are examined. The cost of illness (COI) measure covering medical and work loss impacts, and the willingness to pay (WTP) measure covering COI impacts plus all other impacts to the affected individual.

COI estimates were obtained from literature, health care providers and a survey of 66 cataract patients. The average COI, when surgery is undertaken, is about $2,300 ($1985) for the affected individual and $6,800 for society. These figures account for the fact that approximately 60 percent of those undergoing surgery do so on both eyes, and due to the average sick leave and work loss of up to $1,000 per case. These are substantially larger than the $3,000 to $4,000 literature figures that provide only surgical and hospital expenses for surgical treatment.

Based upon the survey of cataract patients, leisure impacts and a variety of concerns related to cataracts were all rated as more important that the medical costs and work loss incurred by the individual. The average WTP damage measure for the affected individual who undergoes surgery is $11,400 to $14,900 ($12,000 point estimate). For society as a whole, the values range from no less than $16,000 to $22,600. The average WTP damage measure for individuals where surgery has not yet been undertaken ranged from $6,000 to $15,000. The substantial differences between individual and social damage measures are due to insurance and other social costs not directly paid by the affected individual.

A framework is developed to calculate the present value of potential future changes in the incidence of cataracts. To illustrate the framework, using the above $16,600 social WTP value, assuming changes in UV-B cause a five to ten percent increase of cataracts starting in 20 years, and using a four and eight percent discount rate, the present value of potential future damages in the U.S. range from $1 to $12 billion.

Given project resources and time constraints, initial surveys of limited size were conducted to illustrate methods and to obtain preliminary damage estimates. With additional resources, more extensive surveys may be conducted to improve the accuracy of the estimates and to obtain values for ex ante changes in cataract risks.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLES

TABLES
(continued)

FIGURES

1.0 <u>EXECUTIVE SUMMARY</u>

1.1 OBJECTIVES

As part of its Stratospheric Ozone Protection Program, the U.S. Environmental Protection Agency (EPA) is conducting analyses of the effects of ultraviolet radiation (UV-B) on human health (EPA 1986). Among other effects, UV-B may contribute to the incidence of cataracts. This report provides preliminary economic estimates of the damage of incurring cataracts for affected individuals and for society. The methods and measures provided may ultimately be used to assess U.S. damages related to UV-B changes that are postulated to be related to stratospheric ozone depletion. The models, methods and analysis reported herein were selected to conduct an assessment and report within five months for an interim regulatory impact analysis. Given project constraints, initial surveys of limited size were conducted to illustrate methods and obtain preliminary damage estimates. With additional resources, more extensive surveys may be conducted to improve the accuracy of the estimates.

1.2 PROCEDURES

If UV-B is related to cataract formation, increases in UV-B may increase the number of individuals who develop cataracts sufficient to impair vision and may reduce the age of onset of cataracts. If increases in the rate of cataract formation occurs, likely social and economic consequences include:

1. **INCREASED MEDICAL COSTS.** Increased medical costs will be incurred in all phases of treatment if incidence rates increase. Of particular concern are post-surgical complications, especially given extended post-surgical periods as the age of onset and corrective surgery decrease and as life expectancy increases.

2. **INCREASED WORK LOSS.** As cataracts may occur at younger ages, more individuals may experience them during their working years resulting in increased work loss.

3. **INCREASED COSTS FOR CHORES AND CAREGIVING** Increases in the number and severity of cases increases the need for, and incurred costs of, chores and caregiving services performed by others.

4. **OTHER INDIRECT SOCIAL AND ECONOMIC COSTS.** These include unpaid chores and caregiving provided by others, inability to undertake desired activities, discomfort or inconvenience, concern of family members and others, concerns about blindness, surgery, and post-surgical complications.

Two economic measures of cataract damage are examined. The Cost of Illness (COI) measure includes components of damage categories 1 and 2 and is based upon actual expenditures. This is a measure often used, but may understate total values. The Willingness to Pay (WTP) measure estimates an economic measure of the total value of all impacts (1-4). The measures are estimated separately from the perspectives of the affected individuals and for society as a whole.

Data is obtained to estimate COI and WTP measures through:

1. A review of national literature and contacts with Denver area health providers to estimate and verify actual medical treatment costs for use in COI measures.

2. A survey of 66 cataract patients from the Denver metropolitan area to estimate both the COI and WTP economic measures of cataract damages. This limited survey illustrates the WTP value approach and provides both a consistency check on the COI estimates obtained elsewhere and provides preliminary information on the magnitude of WTP and its relationship to COI.

A framework is also provided with which one could calculate aggregate damage estimates under alternative ozone depletion UV-B scenarios using the damages per individual estimated in this or future reports. To demonstrate the implementation of this framework, preliminary data is reported concerning the characteristics and treatment of the cataracts population as a whole. This data was collected through review of the literature, contact with national experts studying cataracts, and from a limited survey of ophthalmologists in the Denver metropolitan area.

1.3 SUMMARY OF FINDINGS

The analysis considers the impacts of cataracts that result in visual acuity of 20/30 or worse, or otherwise impair vision. Impacts less than this are considered by the National Eye Institute to be lens opacities. An increase in the incidence rate of cataracts implies:

   1. Some individuals will be diagnosed with cataracts who otherwise would
      not have had cataracts in their lifetime, although they may have had
      lens opacities.

   2. Those individuals who experience cataracts in either eye would now
      experience cataracts earlier in life.

The summary results presented here and in Table E-1 focus upon damage measures for individuals in the first category. This change is the one most likely to be examined in epidemiology and other health impacts study related to changes in UV-B Incremental damages could be addressed for those in the second category using work loss and post surgery treatment information in this report.

Diagnosis and Treatment. Of those with cataracts, 80 to 90 percent will be diagnosed as having cataracts in both eyes, usually within 5 years. Ultimately 75 to 90 percent (declining with increasing age) will have surgery on one or both eyes, with about 60 percent of those undergoing surgery doing so on both eyes. If surgery is needed on both eyes, it is usually performed as two

Table E-1

Summary of Cataract Damage Estimates[1]

($1986)

		To Patient	To Society
1.	Medical expenses	$ 1,263	$ 5,617
2.	Work loss, sick leave and volunteer work loss in year of surgery.	$ 1,043	$ 1,159
3.	Total cost of illness (COI)	$ 2,306	$ 6,776
4.	Other expenses and caregiving	$ 36	$ 166
5.	Total COI + other expenses and caregiving	$ 2,342	$ 6,942

6.	WTP estimate for all adverse impacts		
	-- Point	$12,000	$16,600[2]
	-- Range	$11,400 - $14,900	$16,600 - $22,600[3]

1   Averaged across approximate treatment and age mix currently existing. All
    data from survey results.

2   Point estimate social WTP = individual WTP ($12,000) plus social costs not
    paid by individual (6,942-2,342=4,600).

3   Range of Social WTP = range of individual WTP + 4,600 plus potential social
    WTP to reduce illness paid by other and ranging from $0 to up to .5 times
    the individual WTP of $12,000. See Section 6.5.

separate procedures. The majority of surgery is now being performed on an outpatient basis taking about one-half day plus a several-week recovery period. A majority of ophthalmologists use the extracapsular extraction procedure, and restore vision with an intraocular lens (IOL) implant. About 30 percent of surgeries result in post-surgical complications requiring follow-up surgical treatment. A substantial portion of surgery patients obtain improvements in nearsightedness or farsightedness.

Medical Treatment Costs. The average total medical cost to society per case treated by surgery is estimated to be about $5,600, including doctor visits, prescription glasses, medications, and surgery related expenses (assuming 60 percent of cases have surgery on both eyes and 40 percent have surgery on one eye). The average surgery cost of just the surgical treatment for both eyes (about $6,200) is roughly double the surgery cost for one eye (about $3,340). The average medical-related cost paid by the affected individual is only $1,263 due to private insurance and Medicare coverage. The medical cost to those 10 to 25 percent (increasing with age) who do not seek surgical treatment is substantially less.

Work Loss. Work and income loss do occur as a result of cataracts. However, since cataracts are incident primarily upon the elderly, the average amount of work loss per case is presently not as substantial as might otherwise be expected. The average annual work loss for survey respondents is about $1,043. The average annual work loss to society for each respondent is about $1,159, slightly higher due to the value of lost volunteer work. These figures may overstate average work loss as the sample is somewhat overrepresentative of the working age population relative to the current cataractous population as a whole.

Chores and Leisure. About one-half of the survey sample indicated that cataracts interfered with their ability to do chores or to participate in desired leisure activities. About a third indicated they used paid or unpaid caregiving services or had other expenses associated with cataracts, with an average samplewide value of these services totaling about $160.

The Relative Importance of the Impacts of Cataracts. Survey respondents ranked
the relative importance of damage categories as seen from the perspective of the
affected individual, not society. Overall the rankings are as follows:

Rank	Category
1 (tie)	Leisure impacts.
1 (tie)	Concerns about eyesight, surgery and possible complications.
3 (tie)	Concerns about needing help from family and friends.
3 (tie)	Medical expenses incurred by the household.
5 (tie)	Ability to earn income.
5 (tie)	Ability to work for reasons other than income.
7	Expenses for services hired.

Damage Measures. Damage measures are based upon actual expenses incurred, and
WTP measures of total damage. The damage measures are best interpreted as
approximate, and apply to the actual damage incurred, not damage avoided through
surgery.

o The average COI to the affected individual where surgery is undertaken
  is $2,306.

o The average COI to society per case where surgery is undertaken is
  $6,776.

o The average WTP total value of damage to the affected individual where
  surgery is undertaken is best estimated as $12,000 with a best range of
  estimates from $11,400 to $14,900.

o The average WTP total value of damage to the affected individual where
  surgery has not yet been undertaken ranges from $6,000 to $15,000.

o   The average WTP total value of damage to society where surgery is undertaken is best estimated as no less than $16,600, with estimates ranging up to $22,600 per case.

o   The ratio of the total social WTP to social COI ranges from 2.4 to 3.7, indicating that COI measures substantially understate economic measures of the impacts of cataracts.

Potential Incremental Cataract Damage in the U.S. Related to Changes in UV-B. A highly simplified calculation (see Chapter 7), assuming changes in UV-B cause an increase the incidence of cataracts in the U.S. by either 5 or 10 percent starting in 20 years, discounted to present values using 4 and 8 percent discount rates, suggests a present value of potential future damages in the low billions (1 to 12 billion) in the U.S.

Damage Worldwide. The focus of this effort has been on cataract damage in the U.S. However, one of the major causes of blindness in developing countries is cataract (Ladnyi and Thylefors, 1983). The estimates vary, but approximately 23 million people world-wide are blind (visual acuity of 20/400 or less) and an estimated 12-15 million of these are blind from cataract. The vast majority of these people live in developing countries (Kupfer, 1984). In developing nations, where the age of onset is earlier, prevalence rates are higher, and treatment is not readily available leading to a much higher percentage of cases resulting in blindness. The average social and individual damage per case, and certainly the total damage, may exceed those in the U.S.

1.4 ORGANIZATION OF THE REPORT

To value increased incidence of an illness requires understanding of the illness and its treatment. Chapter 2 provides a layman's introduction to the characteristics, causes and treatments of cataracts, and the incidence of cataracts in the United States. Chapter 3 discusses conceptual approaches to the estimation of economic measures of damage related to cataracts and discusses the selection of the valuation approach using COI and WTP with a panel of cataract patients. Chapter 4 discusses existing economic estimates on the costs

of cataracts from the literature and health care providers, which represent the value source and measure a typical COI approach would obtain. Chapters 5 and 6 discuss the design, implementation and results of the cataract patient survey. Chapter 7 presents and illustrates a framework for applying the results to estimate potential aggregate cataract related damages in the U.S. due to ozone depletion.

2.0 BACKGROUND ON CATARACTS: CHARACTERISTICS, CAUSES, IMPACTS AND TREATMENTS

2.1 DESCRIPTION OF THE DISEASE[1]

A cataract is defined as an opacity in the eye's normally clear crystalline lens that may or may not interfere with vision. The crystalline lens is located behind the pupil and iris (See Figure 2-1). It helps focus light onto the retina, the light sensitive tissue that lines the inside of the back of the eye. When the lens becomes clouded, the passage of light is obstructed and vision may be impaired. Left untreated, some cataracts may progress and eventually cause blindness. According to data gathered by the Model Reporting Area for Blindness Statistics (MRA), cataracts were the second leading cause of blindness in the United States in 1970 (the last year for which data were collected).

Among the signs that a cataract may be developing are:

   o   Hazy, fuzzy, or blurred vision. Double vision sometimes occurs, but
       this usually goes away as the cataract worsens.

   o   The need for frequent changes in eyeglass prescriptions. When the
       cataract progresses beyond a certain point, these changes no longer
       improve the vision.

   o   A feeling of having a film over the eyes , or of looking through veils
       or a waterfall. A person with a cataract may blink a lot in an effort
       to see better.

   o   Problems with light. For example, night driving becomes harder
       because the cloudy part of the lens scatters the light from oncoming
       headlights, making these lights appear double or dazzling. Also, the
       person with a cataract may have trouble finding the right amount of
       light for reading or close work.

   o   "Second Sight"--a temporary improvement in reading vision experienced
       by some people when their cataract reaches a certain stage of
       development. As the cataract progresses, vision again worsens.

---

1. This section draws heavily on two reports published by the U.S. Department of
   Health and Human Services, National Eye Institute: <u>Cataracts</u>, (1985) and
   <u>Vision Research: A National Plan</u> (1983). Discussion and data can be found
   in these reports, unless otherwise cited.

Figure 1

A Cross-section of the Human Eye
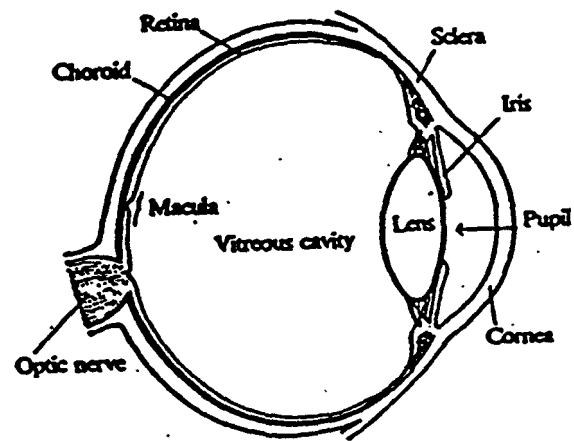
Cataracts may occur as a result of a wide variety of factors including metabolic disorders, exposure to toxic agents, trauma, exposure to radiation, nutritional deficiencies, and hereditary factors. The most common form of cataracts, however, are the so-called senile cataracts found among older individuals and for which no specific causative factor has been identified. Accounting for 85 percent of all cataracts , senile cataracts are associated with aging and develop gradually and painlessly over time. (Kahn 35 et al., 1977.) The impact of a cataract upon vision is dependent both on its size and its location relative to the lens' central axis (where light is focused); some remain small and do not seriously affect vision, but some grow larger and denser until light can no longer pass through, and must be surgically removed for vision to be restored. For the patient, it is the personal or functional aspect of the disease that is most meaningful.

It is estimated that about 60 percent of all Americans between the ages of 65 and 74 have senile cataracts, although this type can also occur at or before the age of 50. About one-fourth of individuals in this age group have impaired vision (commonly defined as visual acuity of 20/40 with best correction) due to cataracts. In the United States today, a person living a normal life span is more likely to undergo a cataract operation than any other major surgical procedure (U.S. Congress, 1985).

Few studies have been conducted to determine the prevalence and incidence of cataracts. Estimates of population prevalence and incidence are based on survey data collected over a specific time interval. The prevalence rate is a ratio of the number of cases of the disease present in the population during that interval, divided by the population at risk for the disease. The incidence rate is the ratio of the number of new cases of the disease arising or first diagnosed during the interval, again divided by the population at risk. Estimates should be interpreted with care for two reasons: problems in definition and classification of cataracts, and limitations of the available sources of data.

The two main sources of population prevalence data for the U.S. are The Framingham Eye Study (1977), and The National Health and Nutrition Examination Survey (NHANES) of the National Center for Health Statistics (1980). The

Framingham Eye Study was a National Eye Institute-supported study conducted from 1973-1975, measuring the prevalence of senile cataracts and other eye diseases among the surviving participants in the Framingham Heart Study supported by the National Heart, Lung, and Blood Institute. In the Framingham Eye Study, 2631 persons over 52 years old received a screening eye examination. A diagnosis of senile cataract was made if the visual acuity was 20/30 or worse, and senile lens changes were present or the lens had been removed. Senile cataract was diagnosed in 12.3 percent of all persons examined. There was a statistically significant difference in the rates in men (10.3 percent) and women (13.8 percent) (P<0.01), which was most marked in those over 75 (Leibowitz et al., 1980). Because these findings come from examinations of white residents in a specific geographic area, the results may not be applicable to the the United States population as a whole. These rates are summarized in Table 2-1.

The NHANES study conducted eye examinations on about 10,000 persons in 35 geographic areas between April 1971 and October 1972. The data collected are from a probability sample of the civilian, noninstitutionalized population, weighted more heavily on low-income groups, older age groups (with an upper limit of 74 years), preschool children, and women of childbearing age. Senile cataract was defined in the study as the presence of similar lens changes consistent with a best visual acuity of 20/30 or worse. Race, education and area of residence were found to affect the prevalence of cataract. The results of these studies are summarized in Table 2-2.

Incidence rates of senile cataracts have not been directly measured due to their slow rate of progression, although estimates of five-year rates have been generated ranging from 1.2 percent at age 55 to 15.3 percent at age 70 using prevalence data from the Framingham eye study. (Podgor et al., 1983, p. 211). Estimates for incidence rates are summarized in Table 2-3.

Estimates for prevalence and incidence of blindness due to cataract in 1970, presented in Table 2-4, are available from the Model Reporting Area study. These data indicate that cataracts (all types) were the 2nd leading cause of blindness in 1970. These estimates are only approximations, however. First, because of underreporting in blindness registries, blindness from cataract is

Table 2-1

Prevalence of Senile Lens Changes and

Senile Cataract or Aphakia by Age and Sex,

Framingham Eye Study, Local Area Only*

Age (Years) and sex	Senile Lens Changes[1] % Diagnosed in One or Both Eyes	Senile Cataract or Aphakia[2] % Diagnosed in One or Both Eyes
52-64	41.7	4.5
Males	37.9	4.3
Females	44.7	4.7
65-74	73.2	18.0
Males	68.1	16.0
Females	76.7	19.3
75-85	91.1	45.9
Males	88.2	40.9
Females	93.0	48.9
TOTAL:	59.2	15.5
Males	54.1	13.2
Females	63.0	17.1

*Source: Podgor et al., 1983, p. 211

[1] Aphakia of senile etiology, early senile lens changes (vacuoles, water clefts, spokes and lamellar separations), late senile lens changes (cortical cuneiform opacities, nuclear sclerosis, posterior subcapsular opacities, and miscellaneous late senile changes).

[2] Aphakia of senile etiology and late lens changes accompanied by visual acuity of 20/30 or worse.

Table 2-2

Prevalence of Cataracts and Prevalence of Cataracts Causing

Decrease in Vision By Age and Sex, 1971-72*

Age Group Both Sexes	Percent Prevalence	Percent Prevalence Causing Decrease in Vision	Number in Thousands
1- 5	.4	.1	19
6-11	.6	--	--
12-17	1.3	.2	50
18-24	2.4	.3	64
25-34	2.8	.2	255
35-44	4.1	.8	191
45-54	12.2	2.6	608
55-64	27.6	10.0	1,860
65-74	57.6	28.5	3,623
Males			
1-74	8.4	3.1	2,889
Females			
1-74	10.9	3.6	3,582
All	9.4	3.4	6,540
Standard Error	.4	--	--

* Source: Provisional Data from the National Health and Nutrition Examination
  Survey of 1971-72.

Table 2-3

Estimated Age-Specific Five-Year Incidences (and Estimated

Standard Errors) in Percent, Framingham, MA, 1973-75

for Senile Lens Changes and Senile Cataracts*

Age (Years)	Senile Lens[1] Changes	Senile Cataracts[2]
55	10.2 (2.4)	1.2 (0.8)
60	16.0 (3.4)	2.4 (1.2)
65	23.3 (4.6)	4.6 (1.8)
70	30.8 (6.6)	8.8 (2.8)
75	36.9 (11.2)	15.3 (5.2)

Source: Podgor et al., 1983, p. 211.

[1] Aphakia of senile etiology, early senile lens changes (vacuoles, water clefts, spokes and lamellar separations), late senile lens changes (cortical cuneiform opacities, nuclear sclerosis, posterior subcapsular opacities, and miscellaneous late senile changes).

[2] Aphakia of senile etiology and late lens changes accompanied by visual acuity of 20/30 or worse.

Table 2-4

Prevalence and Incidence of Cataract Blindness[1]
(per 100,000), from Model Reporting Area for
Blindness Statistics, 1970*

| | | Age | | | |
	All Ages	**45-65**	**65-75**	**75-04**	**≥ 85**
Prevalence	19.2	23.0	52.6	128.4	492.2
Incidence	2.1	3.5	4.9	14.0	40.8

* Source: Kahn and Moorhead, 1973, p.6.

[1] From a group of state blindness registries using as a common definition of blindness best corrected visual acuity of 20/200 or less in the better eye, or visual field limited to 20 degrees in its widest diameter.

likely to vary with socio-economic and demographic factors. Second, the data are 17 years old, and trends in treatment of cataracts have changed dramatically in that time period resulting in higher surgery rates. Thus, caution should be used in comparing rate estimates for blindness from cataracts and rate estimates for cataract prevalence, since factors such as access to medical care and improvements in medical treatment will confound the relationship between cataract and blindness.

After senile cataracts, the most common forms of cataracts are congenital cataracts, which are present at birth or develop within a year after birth; traumatic cataracts, which result from an eye injury or exposure to harmful chemicals; drug-induced cataracts; radiation cataracts; and secondary cataracts, which are the result of complications of eye or general disorders. People who have glaucoma, iritis, uveitis, or ocular tumors may develop cataracts. Diabetes and other metabolic disorders are also associated with cataract.

2.2 CAUSES OF CATARACTS

When a cataract forms, there is a change in the chemical composition of the lens. It is not known what causes these changes, but epidemiological studies have identified several potential risk factors in cataract formation, leading to the conclusion that although the aging process is the leading covariate with cataracts it does not alone account for the opacities that lead to decreased visual acuity. Risk factors have been summarized as follows (National Eye Institute, 1983):

1. Ultraviolet light long wavelength UV (UVL)

   a. Sunlight
   b. Occupational exposure (chemists, laundry workers, currency examiners, dentists, orthopedic technicians, dermatologists)

2. Ionizing radiation (therapeutic and diagnostic, CT scan, X-rays)

3. Radiofrequency and microwave radiation (military, industrial, scientific)

4. Toxic drugs, chemicals and some medications

5. Diabetes

6. Blood pressure (The results of the Framingham Eye Study indicate that elevated blood pressure is associated with the presence of cataract.)

7. Family history (Although senile cataract often runs in families, no studies have been conducted to clarify whether these have a genetic basis or are due to environmental factors such as nutrition or sunlight exposure.)

8. Biochemical agents

One study using the National Health and Nutrition Examination Survey (NHANES) data of 1971-1972 examined the association between cataracts and a number of demographic, environmental and host factors. A multivariate analysis shown in Table 2-5 indicates that cataracts occurred more commonly among blacks, diabetics and rural dwellers, and was also positively associated with increasing age, increasing UV-B radiation and decreasing number of years spent in school (Hiller et al., 1983).

2.3 THE ASSOCIATION BETWEEN UV RADIATION AND CATARACTS

According to a recent review of the literature, the longest standing hypothesis that may account for the development of senile cataracts is that radiant energy, particularly sunlight, is a major factor in the origin of the disease. This concept apparently originated from numerous observations indicating that cataracts occurred more frequently or earlier in persons whose occupations kept them outdoors and that populations living in areas with more hours of sunshine have a higher frequency of cataract than populations from areas with less sunshine (Pitts et al., 1986).

One major finding has been the discovery of biochemical protein changes in the opaque lens material. A characteristic change in certain senile cataracts is the aggregation of lens proteins into larger and larger structures. The aggregation of the lens protein can be the result of exposure to UV radiation leading to photo-oxidation (Kupfer, 1984). Although the epidemiologic evidence relating the formation of cataract to UV radiation is weak, cataract

Table 2-5

Standardized Regression Coefficients for Cataract Derived

from Multivariate Logistic Risk Function Analyses*

Risk Factor	Coefficient
Dependent Variable = Probability of Cataract	
Age	1.20^{a}
Race	0.13^{b}
Sex	0.08
Education	-0.14^{b}
Diabetes	0.21^{a}
Systolic Blood Pressure	0.08
UV-B	0.13^{b}
Residence	0.19^{a}

* Source: Hiller et al., 1983, Table 3, p.243.

[a] $p < 0.005$

[b] $p < 0.05$

can be produced experimentally in mice, rabbits, and monkeys with acute or chronic exposure to UV radiation (Pitts et al., 1986). Cataract has also occurred in humans following acute exposure to UV (Lerman, 1980) and after ingestion of photosensitizing drugs (Cyrlin, 1980 and Lafond et al., 1984).

The optical spectrum is defined as that portion of the electromagnetic spectrum which begins at 190 nanometers (nm) and extends to 3500 nm. The UV portion of the optical spectrum encompasses the 190 to 400 nm waveband. The portion from 290 to 315 nm constitutes UV-B, 315 to 400 nm is UV-A.

Experimental and epidemiological studies yield comparable estimates of the ambient levels of radiant exposure required to induce cataracts (Waxler, 1986a, p. 14). Exposure variables affecting likelihood of cataractogenis have been identified as wavelength, intensity or level of radiant exposure, and time or duration of exposure. These variables, in turn, are a function of altitude and latitude. Ocular damage occurs at lower radiant exposures and shorter exposure durations for shorter wavelengths.

The evidence strongly suggests that decades of exposure to UV-B in the range of 300 nm induces cataracts in humans. In an ecologic study of the relationship between cataract prevalence, altitude and average sunlight exposure, when exposure increased from 7 to 12 hours per day (due to geographical location), the rate of cataract was 3.8 times higher (Brilliant et al., 1983). In another study, cataract prevalence was 58 percent higher for persons exposed to UV-B counts of a city like Tucson as opposed to a city like Albany; and San Antonio had a 28 percent higher cataract prevelance than Philadelphia (Miller et al., 1983).

In their review of the literature, Pitts et al. (1986) conclude that there appears to be a concensus from the epidemiological studies supporting the hypothesis that senile cataracts are associated with higher exposure to sunlight. They note that despite the variety of exposure measurements, employed case definitions of cataract used, methods of ophthalmic examination, and disparities of design and populations studied, the epidemiologic evidence for a causal association of senile cataract with chronic solar UV exposure is biologically plausible, consistent with experimental data, and exhibits a

dose-response relationship. Taken in aggregate, the studies reviewed represent a variety of approaches, using different types of populations, different criteria for cataract, different sampling and statistical methods, and different variables to test the same hypothesis. The authors conclude that despite these differences, the general conclusions of each study are strikingly similar (Pitts et al., 1986). The results of the epidemiological studies they reviewed are summarized in Table 2-6.

In a preliminary attempt to judge the practical implications of the published data, an estimate of the relationship between UV-B exposure and cataract prevalence has been made by Dr. Morris Waxler (1986b) of the FDA, based on four of the best epidemiological studies reported to date. This estimate was adjusted to account for confounding variables such as ecological design of studies, effect of UV-A on the lens in addition to UV-B, effects of nutrition, medication, and other variables, and measurement problems in some studies.

Dr. Waxier's calculations suggest that for every annual increase of 10.0 J/cm^2 in radiation there is an increase of from 3.25 to 8.75 percent in the prevalence of cataracts. These numbers are a tentative attempt to quantify the relationship between UV-B radiation and cataract, and must be substantiated by several more studies before they can be considered confirmed.

2.4 THE IMPACT OF CATARACTS ON LIFESTYLE

Although cataracts cause no physical pain, the rate of progression is so slow that there may often be a period of time before surgery in which the patient's lifestyle is inhibited due to the cataract. No absolute or exact visual requirements can be cited for recommendation of a routine cataract operation, however, some general guidelines are usually followed. The decision for surgery will depend heavily on the patient's needs, and desired level of activity and recreation. Obviously, some people depend on their eyes for their livelihood much more than others. In addition, medical considerations such as the symmetry of the disease process, conditions of the other ocular structures, and the general health of the patient should be taken account of

Table 2-6

Summary of Epidemiologic Studies of

Cataract and Solar UV Exposure*

Population	Measure of Outcome[a,c]	Measure of Sun Exposure	Measure of Association[b]	Author
Cataract cases diagnosed in 11 urban areas of Rumania	"Senile Cataract" (vs. population of area)	Geographic location (south vs. east, west and central areas)	RR:(crude) 1.3 to 2.2	Pacurariu, and Marin, 1973.
MRA:9110 U.S. patients registered as blind; white	Blind from cataract (vs. blind from other selected diseases)	Hours of sunlight in area of residence (<2400 to 3000+)	OR: (both sexes) ages 65 to 74:2.0 to 5.8 (depending on comparison group); 3.3 (for all groups combined) ages 75+:2.6 to 5.5; 3.5	Hiller et al., 1977.
HANES: 3580 whites; probability sample of U.S.	Lens opacity and VA $\leq$ 20/25 (vs. other eye diseases or no eye disease)	As above	OR: (both sexes) ages 65 to 74: 0.14 to 2.7 (depending on comparison group); 1.9 (for all groups combined)	
HANES: 2225 whites and blacks; 1/2-lifetime residents of area sampled	Lens opacity consistent with VA $\leq$ 6/9) (vs. all others in sample)	Ave. daily UV-B counts: a) 6000 vs 2000; b) 4800 vs 3000	RR: (Multiply adjusted) a) 1.58; b) 1.28	Hiller et al., 1983.
Sample of 350 Australian Aborigines (part of eye health survey; see below)	VA<6/16 attributable to a senile lens opacity (vs. all others examined)	a) Ave. daily sunlight hours for area of residence 9.5+vs. 8 b) Annual mean UV-B count for area of residence: 3000 vs. 1000	OR: (crude) a) 4.2 b) 1.8; (2.3 for ages 40+)	Taylor, 1980.

Table 2-6 - Continued

Summary of Epidemiologic Studies of

Cataract and Solar UV Exposure*

Population	Measure of Outcome[a,c]	Measure of Sun Exposure	Measure of Association[b]	Author
Survey of 64,307 Australian Aborigines and 41,254 non-aborigines (self selected)	As above	Ave. daily UV-B count for area of residence: 3000 vs. 1000	RR: (signif. for aborigines only) 3.0 (ages 40 to 59); 2.2 (ages 60+)	Hollows and Moran, 1981.
125,279 Chinese from 7 areas examined as part of blindness screening survey	VA <0.02 and severe senile lens opacity; no dilation; (vs. all others in survey)	Duration of insolation for area of resi-dence (days/year) 2915 vs. 2430	RR: (crude) 22.0	Mao and Hu, 1985.
27,785 Nepales; lifelong residents of rural areas	Senile lens opacities (vs. all others examined)	Ave. daily sunlight hours a) 12 vs. 7; b) 12 (high) vs. 7-9 (low)	OR: (crude) a) 3.8; b) 2.6	Brilliant et al., 1983.

* Source: Pitts et al., 1986.

[a] All studies included aphakic persons among those with senile cataract.

[b] The relative risk or risk ratio (RR) is the rate of cataract in the most highly exposed group in the study, divided by the rate in the least exposed group. The relative odds or odds ratio (OR) is the ratio of cataract cases to noncases in the most highly exposed group, divided by the same ratio in the least exposed group. The higher the RR or OR, the stronger the association between the exposure and outcome variables. A crude rate is one that has not been adjusted for the effects of other cataract risk factors, such as age. Measures of association computed from crude rates can be confounded by the effects of these other risk factors. Adjusted rates are more useful. Both the RR and the OR are valid measures of association. When a disease is rare, they are equivalent, but in the case of senile cataract, which is not a rare condition, the OR will give an overestimation of the RR.

[c] VA = Measured Visual Acuity.

(Liesegang, 1984, p. 559). Preoperative restrictions in activities may
include :

> o   a reduced ability to participate in work activities due to reduced
>   visual acuity, sometimes causing early retirement;
>
> o   a reduced ability to participate in leisure activities such as
>   reading, watching television, and driving;
>
> o   a reduced ability to perform household duties such as shopping and
>   home maintenance; and
>
> o   an increased dependence on others, e.g. family members or hired help,
>   to provide caretaking services such as self care and mobility.

After the operation, physical restrictions are minimal. The surgical wound is
generally healed after six to eight weeks, and the patient is able to resume
normal activites.

2.5 TREATMENT

There is no proven medical treatment that will cure most forms of cataract;
the only treatment is surgery, undertaken to remove the cataract if vision
impairment is severe enough. This usually occurs when the cataract has
progressed to the point that vision problems interfere with one's daily
activities, as outlined above. An optometrist will not usually not refer the
patient to an ophthalmologist for cataract surgery unless vision is worse than
20/40. Visual requirements vary by occupation, but 20/40 is a common
threshold because it is the minimum level of acuity required for a driver's
license in most states. The patient may delay surgery when the perceived cost
of delaying (or forgoing altogether) is less than the perceived costs of
surgery. Another factor affecting the surgery decision is whether one or both
eyes are affected. If the disease is unilateral, the patient may often delay
surgery. It is also important to consider removal of the lens to protect
other parts of the eye, such as the retina, from potential damage due to
disintegration of a mature cataract.

Treatment involves two steps. First, surgery is performed to remove the crystalline lens. Removal of the crystalline lens results in a condition known as aphakia (absence of the lens). Aphakic vision itself may be a significant visual handicap. If the patient is unable or unwilling to take measures for visual correction after cataract extraction, the patient will be functionally blind in the eye despite a "successful" operation.

The second step in treatment is to take measures to correct the aphakia. The alternative methods used to correct vision after cataract surgery are aphakic spectacles, contact lenses, intraocular lenses implanted at the time of cataract surgery or afterward, or surgical alteration of the cornea (refractive surgery). Each has its advantages and disadvantages.

o **Eyeglasses.** After cataract extraction, central vision with eyeglasses may be 20/20, however, significant distortions remain, including image size changes, lens aberrations, blind spots in the visual field, and visual field restrictions (the focal range is fixed). Furthermore, there is a 20 to 25 percent difference in image size between the aphakic and normal eye.

o **Contact Lenses.** Many of the problems associated with cataract eyeglasses are overcome by the use of contact lenses, which result in a 5 to 10 percent image size difference between the aphakic and normal eye. Soft lenses are used most often, although hard lenses and extended wear lenses are also used. Extended wear contact lenses are useful for people who have trouble inserting and removing a contact lens. The rate of use failure increases with age of the patient.

o **Intraocular Lenses.** Since the late 1960s, intraocular lenses (IOLs) have been used in the United States with increasing frequency as an alternative to glasses and contact lenses to restore useful vision following cataract extraction (see Table 2-7). The IOL is made of a plastic material and permanently implanted in the eye, most often during cataract surgery following removal of the natural lens. Because it replaces the natural lens at the same location, it has distinct optical advantages. It usually eliminates or minimizes the

Table 2-7

Correction of Aphakia*

	Percent of Total	
	1973	**1983 (projected[a])**
Eyeglasses	80	20
Hard and Soft Contact Lenses	15	10
Extended Wear Contact Lenses	0	25
Disposable Contact Lenses	0	5
Intraocular Lens Implants	5	40
Refractive Corneal Surgery	--	< 1

*   National Eye Institute, 1983, p.100.

[a]   The Intraocular Lens Industry, Sanford C. Bernstein and Company, Inc., N.Y., NY.

problems with image size, side vision, and depth perception noted by
people who wear cataract eyeglasses. Also, because lens implants
remain in the eye and do not have to be removed, cleaned, and
reinserted, they are more convenient than contact lenses. This is
particularly true for people who have physical problems that would
make it difficult for them to carry out the procedures involved in
using contact lenses.

    O **Refractive Corneal Surgery.** Surgical manipulation of the cornea to
alter refractive power has recently been used for a small number of
aphakic patients. This technique may become an important alternative
in the correction of aphakia, but further laboratory and clinical
studies are needed to gain more information about specific indications
for its use and its long-term safety and efficacy.

There are two major surgical techniques for removing the opaque lens; intra-
capsular extraction, in which the entire lens capsule along with the clouded
lens is removed; and extracapsular extraction, in which the clouded lens is
removed along with the front portion of the lens capsule leaving the rear
portion of the capsule in place. The intracapsular extraction technique is a
time-honored and perfected method and is the easiest to perform. The extra-
capsular method, which involves aspirating the lens out through a hollow
needle, has become more common in recent years (see Table 2-8). The major
advantage of the extracapsular extraction method is that it allows fixation of
several styles of intraocular lenses which reduce the mobility of the IOL,
thus lowering the chances of postoperative complications (Liesegang, 1984,
p.623). However, it also requires more skill on the part of the surgeon, and
the earliest cases by a given surgeon are generally accompanied by a
relatively high rate of complications (Leisegang, 1984, p. 625). It is also
common for the remaining lens tissue to become opacified following the
extracapsular extraction method (a condition called after-cataract),
necessitating further treatment. After-cataracts are usually removed with
laser surgery.

Table 2-8

Trend in Type of Surgical Procedure Used

to Extract Cataract

Year	Extracapsular Procedure	Intracapsular Procedure	Other Procedures
1981[a]	29.4%	68.1%	2.5%
1982	39.3	57.0	3.7
1983	51.9	43.8	4.3
1984[b]	72.0	17.0	11.0

[a] 1981-1983 data from the Hospital Discharge Survey, National Center for Health Statistics, for cataract extractions on patients 65 and over.

[b] Balyeat, 1985, p.104.

The rate of cataract extraction in the United States has increased substantially in the past two decades. The rate of extraction rose from 111 per 100,000 population in 1969 to 168 per 100,000 population in 1978, an annual rate of 4.2 percent. Cataract surgery accounted for 1.6 percent of all operations performed in that year and was done about as often as appendectomy (Dawson and Schwab, 1981, p. 494). Between 1980 and 1985, the rate of cataract surgery has more than doubled, and it is projected to double again by the end of this decade (U.S Congress, 1985, p. 239). A 177 percent increase in the number of cataract operations on Medicare beneficiaries was reported from 1965 to 1977. Today it is the most frequently reimbursed major surgical procedure under the Medicare Program (U.S. Congress, 1985, p. 2).

As seen in Table 2-7, the trend in favor of the use of IOLs to correct aphakic vision has been dramatic. The percentage of cataract patients having IOLs implanted has increased sharply, from 32 percent in 1980 to 85 percent in 1985 (U.S Congress, 1985, p. 241). The majority of lenses implanted today are one of two types, the anterior chamber lens, and the posterior chamber lens. The anterior chamber lens is implanted following the intracapsular extraction method, which removes the lens and the entire capsule. The posterior chamber lens is used following the extracapsular extraction method, and has become more common along with the increased popularity of the extracapsular method (See Table 2-9). The advantages of the extracapsular method of extraction along with the posterior chamber lens are two: the remaining portion of the capsule tends to hold the vitreous humor, a viscous fluid found in the eye, in its normal anatomical position in the back of the eye, and the capsule itself serves as a support for the posterior chamber lens (U.S. Congress, 1985, p. 236). A third type of IOL, the iris supported lens, is anchored by loops to the iris. It was the first type to be used extensively, but is seldom used today (U.S. Congress, 1985, p. 234).

The trend in treatment has been toward the increasing use of outpatient procedures, ambulatory surgery centers (ASC) and the doctor's office for surgery (see Table 2-10). According to the United States Hospital Discharge Survey (HDS), conducted by the National Center for Health Statistics, in 1980 393,000 patients, or approximately 50 percent of cataract surgeries were

Table 2-9

Percent of Intraocular Lens Implanted by Type of Lens

for Each Six Month Period*

Type of Lens	1981 Feb	1981 Aug	1982 Feb	1982 Aug	1983 Feb	1983 Aug	1984 Feb
Anterior Chamber	32	35	37	41	36	32	30
Posterior Chamber	37	43	47	50	58	65	69
Iridocapsular	7	4	3	2	1	<1	<1
Iris Fixation	24	18	13	7	5	2	<1

* Source: U.S. Congress, 1985, p. 236.

Table 2-10

Percent of Procedures Performed in Each

Treatment Setting*

Year	Physician's Office and Ambulatory Surgery Center	Outpatient Hospital	Inpatient Hospital
1985	7	70	23
1986[a]	10	75	15
1987	12	80	8
1988	13	79	8
1989	14	78	8
1990	15	77	8

* Source: U.S. Congress, 1985, p. 248.

[a] Projections based on data that 5% of surgeons in 1985 performed Opthalmic
    Surgery in Physicians' Offices or ASCs.

discharged from non-federal hospitals, with an average length of stay of 3.6
days.   A May 1984 survey of 124 ophthalmologists indicates that outpatient
surgery is becoming more common.   In response to the question "What percent of
your routine cataract surgery is outpatient?," 58 percent of the surgeons
responded in the 0-25 category, 9 percent responded in the 25-50 category, and
33 percent responded in the >50 category (Balyeat, 1985, p. 104.). As
indicated in Table 2-10, inpatient procedures are projected to account for
only 8 percent of surgeries in 1987.   The average length of hospital stay for
inpatient procedures is declining as well, from 3.6 days in 1980 to 2.2 days
in 1984 (U.S. Congress, 1985, p. 248).

Improvements in the design and manufacturing of IOLs and in surgical
techniques have contributed to a reduction in complications following surgery.
Some complications are minor, some are annoying, some are visually disabling,
and some are potentially blinding.   Complications may be due to surgical
technique or IOL design.   Ophthalmic surgeons generally feel that 95 percent
of cataract patients achieve "technical success," which refers to a lack of
significant complications related to the removal of the opaque lens (but does
not account for underlying abnormalities of the retina or optic nerve, which
can seriously interfere with the final visual capability). When IOL implants
are used, complications may occur in an additional 2 to 3 percent of cataract
patients (U.S. Congress, 1985, p. 241).   The basic cataract operation is made
somewhat more technically difficult by implant placement, so that there is a
slightly greater likelihood of damage to the cornea, iris, or vitreous body
(the area of the eye located behind the lens).   Complications may also be due
to the implant itself, such as lens dislocation or chronic inflammation (U.S.
Congress, 1985, p. 241).   The incidence of complications is relatively low,
but is cumulative with longevity.   The long-term effects of wearing an IOL
(for several decades) are unknown, thus, if IOLs are implanted on younger
patients, complications may become a more significant factor.

With the extracapsular extraction method and posterior chamber IOL there is a
tendency for after-cataract to develop in some percentage of patients;
estimates vary from 15 percent (Boulder Valley Eye Clinic, personal
conversation with personnel) to 40 to 50 percent (U.S. Congress, 1985, p.
236).   This is a condition in which the remaining portion of the lens capsule

becomes somewhat opacified usually within six months after the operation. To restore vision, an incision is made in the capsular membrane with a surgical knife or a non-heat producing (nd:YAG) laser. The laser treatment is a simple procedure and is atraumatic for the remainder of the structures in the patient's eye (U.S. Congress, 1985, p. 236). Despite this tendency, the extracapsular extraction/posterior chamber IOL treatment method is currently the most popular for the medical reasons outlined above, and also due to the ease and simplicity of treatment of the after-cataract with a cold laser.

According to the above mentioned survey of ophthalmologists, the typical uncomplicated cataract extraction and IOL implant involves a 30 minute operation and a total of 45 minutes in the operating room (Balyeat, 1985, p. 104). The patient spends about three hours in the hospital or doctor's office following surgery (U.S. Congress, 1985, p. 2).

With the loss of the normal crystalline lens, the near-ultraviolet light transmitted through the cornea from sunlight can potentially cause photochemical retinal damage. Use of either glasses or IOLs specifically designed to filter out ultraviolet light has been emphasized recently as a post-surgical protective measure.

3.0 ECONOMIC CONCEPTS, MEASURES, MODELS AND METHODS TO VALUE CHANGES IN CATARACT INCIDENCE AND SEVERITY

There is a substantial literature concerning the economic measurement of values for the risks of adverse health effects that applies quite well to changes in the incidence and severity of cataracts (See Chestnut and Violette 1985, Rowe and Chestnut 1985, 1986 and Dickie, et al. 1986 for recent reviews). This chapter sets the foundation for the selection and application of the valuation methods applied and considers:

- General concepts and sources of value for changes in adverse health effects such as cataracts, in Section 3.1.
- General measures of value for changes in health status, including the Cost of Illness (COI) and Willingness to Pay (WTP) measures, in Section 3.2.
- General models of value of changes in health status are discussed in Section 3.3, and for cataracts in Section 3.4.
- General cataract valuation methods, issues and the survey design and survey of cataract patients is discussed in Section 3.5.

3.1 CONCEPTS AND SOURCES OF VALUE FOR CHANGES IN ADVERSE HEALTH EFFECTS

The economic concept of value from changes in health status is equal to the change in well-being (also referred to as utility) from a change in health status. The vaue of improvements in health status is referred to as the benefits of improved well-being, and the value of degradations in health status is referred to as the damage of reduced well-being. Changes in health status may result in changes in well-being for the affected individual and for others in society.

Values for changes in health status arise from many different sources. For example, if increases in UV-B increase the incidence and rate of formation of cataracts leading to reduced vision at earlier ages, many subsequent effects

will occur that have an impact on the well-being of the affected individual and others in society including:

1. **Increased Medical Costs.** Increased incidence and severity of cataracts may increase pre-surgery treatment costs, increase the probability that cataract surgery will be required in one's lifetime or move the date of surgery forward in time, and increase post cataract surgery costs or complications as that period will also be extended.

2. **Increased Work Loss.** As cataracts occur at younger ages, more individuals will experience them during their working years resulting in increased time off work, lower productivity and lower wages. Psychic losses may also occur due to the reduced ability to contribute to society, aside from the ability to generate income.

3. **Increased Costs for Paid Chores, Caregiving,** etc. Increases in the number and severity of cataracts increase the need, and incurred costs, for chores and caregiving performed for pay by others.

4. **Increased Disutility Related to Reduced Leisure Activities.** Reduced eyesight reduces the ability to participate in desired activities, household chores and unpaid work.

5. **Increased Disutility Related to Discomfort.** As cataracts increase more discomfort may be experienced. While physical discomfort in the eyes is minimal from cataracts, there may be psychic discomfort from concerns about blindness or surgery and post-surgical complications.

6. **Increased Unpaid Caregiving and Chores.** As eyesight deteriorates other friends and family members provide increased levels of caregiving and chores to assist the affected individual. This may provide increased well-being to the caregiver to be able to assist, but at the cost of time, effort, expenditures and ability participate with the affected individual in other more desirable activities.

7. **Other Effects.** These include **risk**[1] and the value to others to reduce risks or severity of adverse effects to the affected individuals.

_____

1. Risk premiums may also enter into the value of changes in health status. A change in environmental conditions may not mean an absolute change in illness for any particular individual, but rather imply changes in the likelihood of illness for everyone in a given population group. What is often desired is willingness to pay (WTP) for changes in the probability of difficult levels of illness, which may differ from the the WTP for a specific change in illness weighted by the change in probability of the illness. The difference could be due to uncertainty, risk premiums and actual events experiencd. While potentially important, these risk premiums are not considered in this analysis as discussed in Section 3.5 below.

Prevention of cataracts will reduce adverse impacts on well-being, and there-fore, have a value to society.

3.2 MEASURES OF VALUE FOR CHANGES IN HEALTH STATUS

Numerous empirical measures of value related to changes in health status are found in the literature. Empirically, the willingness-to-pay measure is the most operationally effective, theoretically correct and encompassing measure of impacts to the individual. Other measures are often used in other circumstances as data availability dictates.

3.2.1 <u>The Willingness-To-Pay and Willigness-To-Accept Measures</u>

The theoretically correct economic measure used to quantify the value of changes in health status is the change in income that results in the same change in well-being as the change in health status, or the change in income that offsets the change in well-being from the change in health status.[2] These measures are two variations of what is known as the consumer's surplus measure of changes in well-being.[3]

The most encompassing operational measure of the value of a change in health status is to determine the maximum amount of other goods and services, in dollar terms, the individual (or society as a whole) would be willing to give up to obtain a desired change in health status, which is referred to as willingnes-to-pay (WTP). Because an individual has a finite amount of resources (or income) to allocate among competing desired uses, the maximum amount of these resources he is willing to allocate to a particular use is a reflection of the value of that use.

---

2. A change in health status may simply be a change in the probabilities of alternative health end points, or a change in severity or frequency of alternative health states.
3. For exact definitions of consumer's surplus measures see Freeman (1979). Under general conditions the two types of general measures identified above are approximately equal. See Randall and Stoll (1980) and Willig (1976).

Alternatively, one could consider the minimum amount one would be willing to accept (WTA) to allow an undesirable change in health status. Due to practical issues in obtaining WTP and WTA measures, WTP measures are the most often used, although conceptually they need not be more appropriate than WTA measures and are almost always less than WTA measures (Gregory 1986). The concepts of WTP and WTA can be readily related to the technical consumer's surplus measures of value most often used by economists. For definitions and details, the reader is referred to Freeman (1979) and Chestnut and Violette (1985).

The amount an individual will be willing to pay to reduce health incidences will depend upon the effects of the health incidence upon their expenditures, ability to generate income, activities, and general sense of well-being; i.e., those sources of value identified above. The WTP will also depend upon the ability of, and costs to, the individual to mitigate adverse impacts.

3.2.2 **The Cost of Illness Measure**

Perhaps the most frequently used approach for valuing changes in health status has been the cost of illness (COI) measure following or modifying the original work of Rice (1966). Reviews of this approach and applications can be found in Hu and Sandifer (1981), Institute of Medicine (1981), and Chestnut and Violette (1985). Recent prominent applications include Manuel et al. (1983), Hartunian et al. (1980), and Mitchell and Vernon (1986).

The general COI approach to valuing changes in illness is to estimate work loss and medical expenditures related to changes in health status (categories 1 and 2 above). For changes in illness expected to be associated with changes in environmental pollution, COI measures are typically obtained for the existing level of illness. Then an X% change in illness is predicted to result in an X% change in COI.

COI measures are frequently used due to the relative availability of data to conduct the analysis, but they have serious limitations. Utility maximizing health production function models (see Section 3.3 below) generally conclude that a WTP measure can be expected to exceed COI measures for a change in health

status due to the omission of impact categories 3-7 above and because the COI approach ignores averting and mitigating behavior on the part of the individual, which may reduce the estimate of current health effects while missing the value of the averting behavior undertaken.

Research by Rowe and Chestnut (1986) found, at least for a panel of asthmatics, that WTP by the affected individual exceeded COI by about a factor of 2 for changes in asthma severity. The ratio of WTP to COI for society as a whole was estimated to be between 1.5 and 2.0. Ongoing research by Chestnut, et al. also finds that WTP significantly exceeds COI for changes in angina attacks by individuals suffering from angina pectoris, and that WTP per angina incident avoided only slightly exceeds defensive expenditures per incident avoided, as would be predicted by economic theory.

3.2.3 Direct Versus Indirect Cost Measures

Some researchers have categorized the impacts of adverse health impacts into what are called direct and indirect measures of damages. The direct measures are defined to encompass all out-of-pocket financial costs, such as medical care, work loss, paid chores and paid caregiving. The measure called indirect costs most often refers to those changes in well-being not associated with actual expenditures, such as inability to participate in desired activities, discomfort and family provided caregiving. These two measures simply recut total WTP into values related to monetary and non-monetary impacts, but differ slightly from the traditional COI measure by including paid chores and caregiving in the monetary category.

3.2.4 Individual Versus Total Social Cost Measures

The measurement of total damages (benefits) of a change in health status is generally measured by summing the WTP measure of benefits across all affected individuals. [4]

This includes the individuals for whom the health status has changed as well as others in society who may be affected. The total social value of changes in illness may differ, and most likely exceed, the change in value for those individuals whose health is actually affected. This is because:

o   some costs in categories 1, 2 and 3 above are covered by others through insurance, medicare, workman's compensation and other similar programs and may not be perceived as a damage to the affected individual, but are a damage to society as a whole;

o   caregiving is sometimes provided by others at no cost to the affected individual, which may entail time, effort and expenditures by these other individuals (category 6 above); and

o   of suffering experienced by others and altruism -- the willingness of some individuals to pay to protect the health of others due to personal discomfort and for the good of society.

In summary, total social willingness-to-pay (WTP_S) and cost-of-illness (COI_S) measures, which are the policy relevant measures, equal the values to the individual based upon damages they experience (WTP_I, COI_I) plus other costs and damages incurred by others in society.

---

4.   This kind of aggregation is often criticized because it implies acceptance of the current distribution of income. WTP is obviously constrained by the individual's income. This approach simply makes use of the concept that the chosen allocation of scarce resources (income) does (in the private sector) and should (in the public sector) reflect the relative utility of the goods and services among which it is allocated. The problem is that using WTP to determine the allocation of public resources implies that more weight will be given to those with more money, as is the case in the private sector as well. Criticism of this approach on this basis generally reflects disatis-faction with the underlying distribution of income, rather than a criticism of the concept of WTP itself.

The effect of insurance has been adressed in some recent analyses (Rowe and Chestnut 1985, 1986; Chestnut, et al., in progress), but few have explicitly measured caregiving or altruism values (Needleman, 1976).

3.2.5 Other Measures

Other measures are sometimes used in the literature. These typically include work loss days, restricted activity days, and the like. These measures are typically first quantified in terms of the number of units, and then a price per unit is attached. Some estimates of these measures for aggregate visual disorders are given in Chapter 4; otherwise these measures will not be further discussed in this report. The fact that these measures represent only a fraction of total value is obvious from the above list of sources of value from health status changes.

3.3 GENERAL ECONOMIC MODELS OF THE VALUE OF ADVERSE HEALTH IMPACTS WITH IMPLICATIONS FOR CATARACT VALUATION

3.3.1 Health Production Function Models

Health production function (HPF) models have been employed by Harrington and Portney (1982) and Gerking et al. (1983) to illustrate how changes in health status may be valued, the level of defensive expenditures and activities the individual will choose to undertake, how epidemiological analyses can be affected when defensive expenditures are ignored, and the components of WTP and, therefore, how WTP and COI measures theoretically compare.

These models are summarized in Rowe and Chestnut (1985) and Chestnut and Violette (1985). For brevity, we simply present a summary of the model implications.

1. The HPF models use many simplifying assumptions, not all of which are easily accepted. Generalizations of the models (discussed in Rowe and Chestnut, 1985) greatly add to complexity, but do not change the basic conclusions outlined below.

2. Individuals will engage in defensive efforts to minimize adverse health
    effects to the point where marginal benefits equal the marginal costs
    in time and money for defensive efforts. The benefits of defensive
    efforts include improvement in utility (well-being); medical costs no
    longer incurred, and the opportunity cost of time no longer spent sick.
    The amount of defensive efforts undertaken depends upon the
    effectiveness of these efforts and their associated costs.

3. An individual's WTP to reduce risks of adverse health effects
    associated with exposures to air pollution is expected to include
    values related to the following damage categories:

    i.   Medical expenditures for treatment of illness.
    ii. Disutility associated with income forgone due to time off from
         work, lower wages or lower productivity at work due to illness.
    iii. Disutility of loss of ability to participate in desired leisure
         activities, household chores, child care and other activities.
    iv. Disutility of discomfort due to illness.
    v.   Disutility of mitigating behavior to prevent illness
         (preventive health care expenditures, inconvenience of activity
         changes, including when and where to work, recreate and live,
         etc.).

4. COI estimates, based upon medical costs and workloss (categories 1 and
    2) for health incidents measured by epidemiology studies, will
    understate WTP to reduce health impacts by missing the value of
    defensive behavior taken to reduce adverse health incidents and by
    ignoring the discomfort and change in lifestyle incurred as a result of
    adverse health incidents.

3.3.2 <u>Implications of HPF Models for the Case of Cataracts</u>

Combining the physical and temporal characteristics of cataracts with the
results of the HPF models provides several implications for the analysis of
increases in cataracts due to increases in UV-B.

o Due to the long-term aspects and characteristics of exposure to UV-B,
   there exists limited mitigating and averting behavior to reduce the
   onset of cataract formation and subsequent impacts. Therefore, while
   these efforts can be measured, they will likely yield poor information
   for use in valuation (see also Section 3.5 below).

o WTP for the individual and society is likely to exceed the corresponding
   COI measure.

o Because of the age at which cataracts start to interfere with activities
   and the recent and ongoing improvements in treatment (surgical)
   procedures, work loss may a relatively small component of total value as
   compared to other health effects, although increases in the rate of
   cataract cases may mean more cases at earlier ages and therefore a
   higher percent of cases in which work loss is incurred.

o Because averting and responsive behavior is unlikely, on a day-to-day
   basis, to have a substantive impact on the long-term cataract formation
   process, the use of daily diaries relating perceived causes on given
   days to health symptoms and behavior on those days to review value (as
   used in Rowe and Chestnut, 1985) should not be pursued with cataract
   patients (see also Section 3.5 below).

3.4 MODELS FOR VALUING CHANGES IN CATARACTS FOR THE AFFECTED INDIVIDUAL

Introduction

Increases in the incidence and rate of formation of cataracts means:

Group 1.   Some individuals will be diagnosed with cataracts who otherwise
           would not have had cataracts in their lifetime.
Group 2.   Those individuals who experience cataracts in either scenario,
           would now experience cataracts earlier in life.

This section analyzes these impacts and concludes that the most significant incremental damages due to increases in UV-B may be to those individuals who otherwise would not have had incurred cataracts in their lifetime. Therefore, subsequent empirical estimation in Chapters 4-7 focuses upon damage estimates for this group. However, because many individuals may incur cataract at an earlier age, the total incremental damage for all of these individuals may also be substantial.

A Simple Model of Impacts Through Time

As identified in Chapter 2, cataracts is a continual and progressive illness. Several possible cataract outcome states are possible during one's lifetime, as summarized in Figure 3-1.

With increases in UV-B radiation, the probability of outcomes 2-6 increase relative to outcome 1, and for those who would have been in outcome 2 or 7 without the increase, the probability of outcome 3-6 increases relative to outcome 2 and 7; i.e. the incidence of detectable cataracts increases, and for those who would have incurred cataracts in either UV-B scenario, the probability of requiring surgery increases.

The incremental damages for individuals in group 1 are represented in Figure 3-2, discussed below. The incremental damages for group 2 are presented in Figure 3-3 (for those individuals where visual acuity increases after surgery). In the following discussions we use the following symbols:

t = Time

ELE = Expected life expectancy (age)

t_0 = Time of onset of detectable cataracts

t_s = Time when cataracts become severe enough to warrant surgery

t_c = The current time period when changes in UV-B occur.

VA = Visual acuity. Vision improves moving up the VA axis. After onset and prior to surgery, $VA=f_1(t)$ at existing levels of UV-B, and $f_2(t)$ at increased levels of UV-B.

Figure 3-1

Simplified Cataract Outcome States

Cataract Formation

Cataracts in One or Both Eyes

Cataracts in Both Eyes

Cataracts in One Eye

Surgery Warranted (One or Both Eyes)

Surgery Undertaken (One or Both Eyes)

Outcome 1
No Cataracts

Outcome 2
Surgery not
Warranted

Outcome 3
Surgery not
undertaken

OUTCOME 4
Vision
improved with
no complication

OUTCOME 5
Vision
improved with
complications

OUTCOME 6
No
improvement or
worsening of
vision

Outcome 7
Surgery not
Warranted

VA' = Visual acuity level without cataracts. For simplicity, we assume VA' is constant over time to abstract away from the effects of other eye ailments.

VA'' = Visual acuity level after cataract surgery, also assumed constant once the individual recovers from surgery and any possible complications that will be corrected. VA'' may be less than or greater than VA'.

VA_c = The critical visual acuity level at which which surgery is recommended.

M = Well-being impacts related to cataracts, which equals the sum of medical treatments, work loss, activity effects, etc.

M_c = M prior to surgery = $M_c(VA)$

M_s = Expected impacts and costs related to surgery including the possibility of complications. Presume this to be constant for this analysis.

M_a = Post-surgery impacts on well-being.

## The Welfare Impacts Of Incurring Cataracts

The damage of increasing the probabiltiy of cataracts, for one who does not have the disease, is equal to the discounted present value of changes in the risks of current and future welfare impacts.

In Figure 3-2 at t_0 cataracts start to appreciably reduce the ability to see (visual quality) until t_s when surgery is recommended. Up to this point, well-being is reduced by the pre-surgery damage represented by the area abc (with value M_c). At time t_s surgery may be forgone and utility is further reduced corresponding to the cross-hatched area bcfg, compared to not incurring cataracts. Surgery might be forgone when the expected ELE occurs near t_s, or where the impacts of impaired vision are minimal so as not to merit the monetary and psychological costs of surgery.

If surgery is undertaken, well-being is further decreased by the costs and psychic effects of surgery (M_s), and post-surgery complications and costs (M_a). Surgery is, of course, undertaken when the perceived damages avoided by surgery are greater than the net damages (including costs) of undertaking surgery.

Figure 3-2

The Welfare Effects of Decreasing the Age of Onset

For those Who Will Develop Cataracts in Their Lifetime*
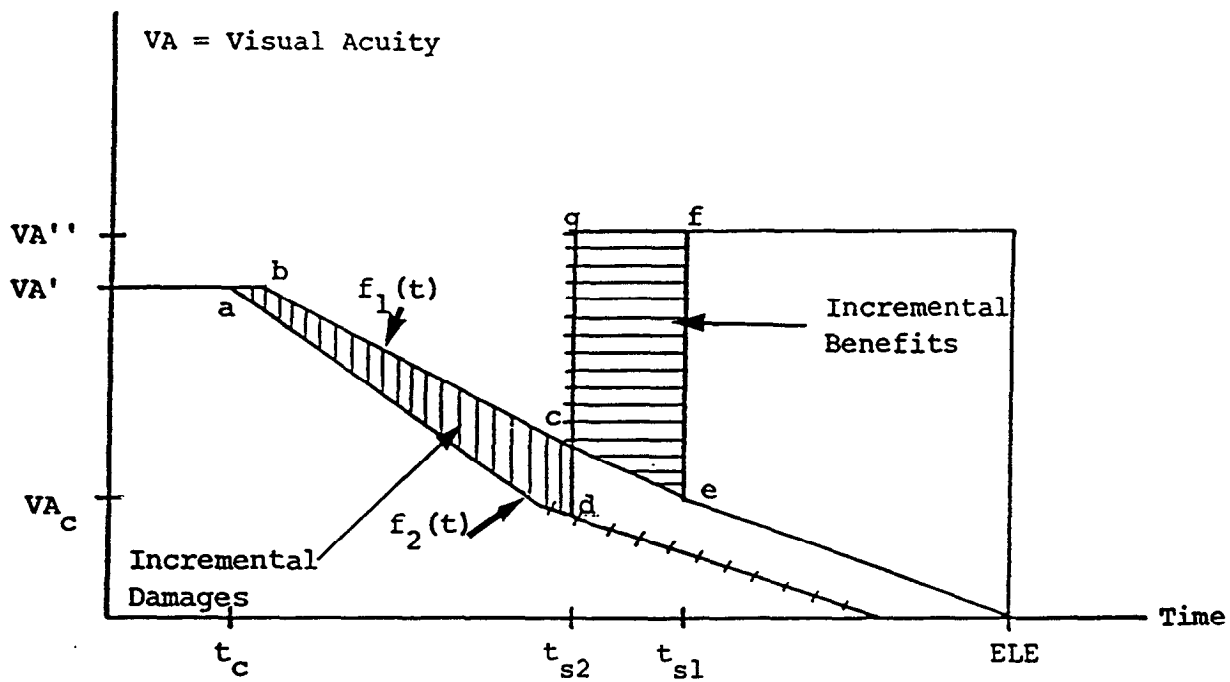
* Presuming surgery occurs when VA=VA$_c$, and VA'' > VA'. If VA'' < VA', then the incremental benefits area is smaller.

Evidence suggests there may often be post-surgery improvements in well-being, as compared to not having had cataracts (VQ″ > VQ′ as in Figure 3-2, Case A). For example, nearsightedness may also be improved. However, as compared to not having incurred cataracts, it is unlikely that the probability and present value of improved vision after surgery at some future time, minus the present value of reduced well-being prior to t_s (M_c), plus the surgery and post-surgery costs (M_s+M_a), would result in a net increase in well-being due to having cataracts.

The Welfare Impacts Of Increasing The Rate of Formation of Cataracts

For some individuals, increases in UV-B will simply reduce the age of onset and surgery for cataracts, as shown in Figure 3-3. In this case, at t_c UV-B increase and the rate of decline in vision follows $f_2(t)$ rather than $f_1(t)$. For the period t_c to t_{s2}, vision and welfare, are reduced corresponding to the difference in monetary and lifestyle costs associated with the area abcd. Because these incremental visual acuity impacts occur at earlier ages, they may be associated with substantially more work loss and other incremental welfare impacts.

If surgery is forgone, well-being is further reduced by the loss of utility associated with the unshaded area between $f_1(t)$ and $f_2(t)$ between t_{s2} and ELE. If ELE occurs near to t_{s2}, or if the welfare impacts are small, then it is unlikely that the costs of surgery will merit the discounted future benefits, surgery will be forgone, and the effect of increases in UV-B will be absolutely negative.

If surgery is undertaken, surgery related impacts and costs, M_s, are incurred, yet vision is improved earlier than would have occurred without the increase in UV-B. This improvement is represented by the shaded area cefg.

It is possible the incremental welfare value of visual acuity improvements, represented with the area cefg, exceed the incremental welfare value of earlier decrements in visual acuity, represented by the area abcd. However, the incremental damages will occur earlier in time, when work loss and lifestyle impacts may be most severe, and incremental benefits will occur later in time, when the welfare benefits may be smaller. When combined with discounting of

future incremental damages and benefits, it is likely the present value of the net incremental change in welfare from incurring cataracts at earlier ages will be negative.

3.5 VALUATION METHODS, APPLICATION ISSUES AND METHOD SELECTION

3.5.1 <u>Valuation Methods</u>

COI and Direct Cost Approaches

The COI and direct cost approach s are attempts to measure the work loss and medical costs associated with changes in illness (COI approach) plus other quantifiable out of pocket costs (direct cost approach). Most often these measures are estimated through available data bases and literature, but can also be obtained through survey work. Due to the incomplete nature of these measures, and the fact that data on these cost measures is often unavailable or incomplete, these approaches are only suggested to complement a more complete WTP measure. The approach next presumes an X% change in adverse health effects results in a comparable X% change in COI. The cost and effect of mitigating or defensive actions, as well as values for indirect effects are not considered. Available literature and data for use in a COI measure approach is examined in Chapter 4.

WTP Surveys

Contingent valuation (CV), or willingness to pay (WTP) surveys ask subjects for estimates of the total value to prevent or reduce specified adverse health effects or risks of adverse health effects. These surveys can be used to both improve the estimates of medical costs , work loss, other direct costs, as well as to quantify the level and value of indirect costs related to activity effects, discomfort, caregiving and the like. These approaches may also be combined with other valuation approaches in the survey design. This approach has been used successfully with panels of asthmatics and angina patients (Rowe and Chestnut 1985, 1986; and Chestnut, et al. in progress).

There is a substantial literature concerning the application strengths and weaknesses of the CV-WTP survey valuation approach. (Cummings et al. 1986, Mitchell and Carson 1987). However, when applied to adverse health effects actually experienced, the approach is on relatively firm ground as the good to be valued is highly familiar to the respondent (Rowe and Chestnut 1986).

Defensive Expenditures and Behavioral Adjustment Approach

Following the HPF models, averting and responsive behavior and expenditures can be used to value changes in well-being from changes in potential adverse health effects, has been done with the angina and asthma patients (Rowe and Chestnut 1985, Chestnut et al. 1987).

The defensive expenditures approach is to identify averting expenditures and the perceived adverse health effect that has been avoided to imply a minimum value per health incident. For example, an individual may pay someone $X to perform a task that they would desire to do themselves if no adverse health impact were to occur in order to avoid the likelihood of N adverse health effects (such as angina attacks). Then the revealed value per angina attack is at least as large as $X/N.

Alternatively one might observe expenditures for medications and equipment to avoid adverse health effects, or measure changes in behavior, such as recreational habits, to minimize adverse health effects. Then combined with a value of this change in behavior and the perceived or estimated change in adverse health effects, a minimum value of the health effect avoided is revealed.

There are several limitations with this general valuation approach including:

  o Technological constraints. One may be limited in the technology that can be used to avoid adverse health impacts. This may mean that at a given cost more protection against adverse health may be desired but cannot be produced. Also, the production function may be lumpy, i.e., one may be able to avoid some adverse health impacts at low cost but to avoid more impacts may require a substantially more dramatic technology

such as surgery. As a result, the value of the marginal health impact can only be revealed to be between the price of the last and next attack avoided, which could range from a few cents to thousands of dollars.

o Actual and perceived effectiveness of averting behavior. The perceived effectiveness of an averting behavior is what is relevant in calculating the value of averting behavior. However, the perceived effectiveness may be unknown to the individual or incorrectly estimated.

For cataracts, it appears that there is little to work with in terms of averting behavior and expenditures, and as the limitations of this approach are quite dramatic in this case, this approach is not recommended.

Relative Values/Rankings

This approach addresses the relative value, or ranking, of alternative adverse health effects (e.g., a cough versus a headache), alternative impacts of an adverse health effect (e.g., workloss versus leisure impacts), or alternative risks (e.g., a 10% change in angina risk versus a 1% change in heart attack risk). The approach has particular merit in checking the consistency of responses obtained with other approaches (such as COI and WTP), and in implying relative values for unquantified health effects and risk levels based upon health effects and risk for which value estimates do exist.

3.5.2 Valuation Issues

Several issues are of importance in addressing the value of adverse affects on well-being associated with cataracts.

Defining the Adverse Health Effect

The adverse health effect that should be valued is that which individuals will most likely experience. For most cataract patients, this inclues the impacts prior to surgery, surgery impacts (including costs plus inconvenience) and any post-surgical impacts. Because very few patients any longer forgo surgery and go blind, damage valuation generally should not include values related to

blindness, although fears of blindness and after surgery impacts are incurred and are valid damages. In summary, one must be careful to value the damages that will be incurred, not those forgone by undertaking surgery.

Ex Ante versus Ex Post Valuation and Certainty Versus Uncertainty

There are two different types of values that depend upon the timing of the adverse health effects.

- o Ex ante values are stated or revealed values in anticipation of potential health effects.

- o Ex post values are stated or revealed values for health effects that have actually occurred.

Revealed ex ante and ex post value may differ due to differences in the perceived and actual event, and due to the existence and valuation of uncertainty.

Environmental quality changes often involve uncertain changes in the level of risk of adverse health effects, which may have uncertain welfare implications. Policy analysis of this change generally calls for an ex ante value of an uncertain change in health risk (Graham, 1981; Chavas, Bishop and Segerson, 1986). Consider, for example, the value of changing the risks of incurring cataracts from 20% to 22%. The value of this risk may not equal 2% of the value of the certain outcome of incurring cataracts due to risk premiums, which may be positive, zero or negative. I.e., valuing of an event once it occurs is under a situation of certainty, but prior to its occurrance is under uncertainty as is actually faced in policy analyses.

3.5.3 Method Selection and Rationale

Based upon the above models and analysis issues, the empirical analysis is focused upon estimating values where the largest per affected individual are expected to occur: the value of impacts for new cataract cases.

To estimate the value of incremental cataract risks (or cases), two approaches are implemented:

1. Use of available literature and contact with care providers to determine the range of medical costs typically experienced (Chapter 4).

2. A limited survey of cataract patients to provide both complete COI and WTP value measures (Chapters 5 and 6). A patient survey allows a more comprehensive examination of COI type impacts than can typically be found in the literature and through care providers, and can examine the relative importance and value of impacts to leisure, discomfort, fear, affects on family and so forth.

Additional data and assumptions about the cataractous population as a whole, to be used in calculating average damage per case and to compute aggregate damage for a change in the rate of incidence is based upon available data (Chapters 2 and 4) and a limited survey of Ophthalmologists (Chapter 7).

These methods were selected to improve the understanding of the impacts of cataracts to affected individual and to obtain defensible and accuracy value estimates for affected individuals.

As noted above, it may be argued that the valuation of health risks is conceptually performed most appropriately, for policy analysis, in an ex ante uncertainty perspective. For example, one might combine the WTP and defensive expenditures approach to obtain a WTP to reduce the incremental risks of cataracts. However, for an ex ante health risk valuation to provide accurate and robust results, particularily using a contingent valuation framework, requires the researcher and respondent to accurately and consistently understand the impacts that are at risk. These impacts include the COI and other impacts (discomfort, family effect, risk to eyesight, etc) that might be experienced.

In the case of recurrent adverse health effects (asthma, angina, headaches, etc.), data gathered from those who have experienced the adverse health effect and risk future adverse health effects can provide accurate ex ante health risk valuations based upon their ex post experience. However, cataract risk, as a one-time event, cannot be valued ex ante by those most familiar with cataracts (i.e., those past and present cataract patients). To obtain complete costs and values for those most familiar with cataracts, one must work with past or present cataract patients.

The literature on the costs and lifestyle impacts of cataracts (reviewed in Chapter 4) is considerably deficient. Therefore, both the researcher and individual providing values in an ex ante valuation must do so based upon per-ceived, and potentially inaccuract, information about the impacts of cataracts. This would reduce the accuracy and robustness of the results of any ex ante valuation. This factor, combined with the requirement of considering values for small percentage changes in risks, leans heavily against against an ex ante valuation for cataract risks until additional information on actual impacts can be gathered, such as in the survey reported upon in Chapters 5 and 6.

The ex post survey approach allows improvement in the COI measure, which is frequently used and understood in many policy arena; provides an improved understanding of the total impacts to the cataract patient and a monetary WTP measure of total damage actually incurred; and provides WTP values that may be directly multiplied by estimates of the expected number of incremental cataract cases for an aggregate valuation of UV-B impacts. This occurs at the loss of the incorporation of risk premiums in the assessment.

In future work, the costs and impacts of cataracts gathered in this analysis may be used to more effectively implement an ex ante valuation than could currently be performed. Futhure research could also include estimating the value of impacts to family members, friends and others in society, which is not considered here due to project resource constraints.